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DATA PROCESSING REQUIREMENT FOR A DEEP TOWED MULTI-CHANNEL ARRA--ETC(U)
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(6) DATA PROCESSING REQUIREMENT FOR A

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SUMMARY

Data Processing of the deep towed seismic multi-channel array data can be accomplished by the proposed CDC Cyber 170 System and a dedicated sea going mini based computer system. Partitioning of the processing load into two categories, Interactive I/O limited and Computation Bound, makes it possible to use each system in a cost effective efficient manner. Demultiplex Edit and Static Operations can all be performed at sea using the mini based system. In addition, velocity analysis interpetation and seismic display can be performed on the system at the NORDA site. Computation based algorithms: Semblance Velocity Analysis, Normal Moveout and Stack, Migration Deconvolution, Band Pass Filtering, Amplitude recovery etc., can all be performed on the new CDC Cyber 170 system.

I. INTRODUCTION

The reduction of seismic array data consists of several processing steps: Demultiplex, Edit, Static Corrections, Common Depth Point (CDP) Gather, Velocity Analysis, Normal Moveout, Stack, Deconvolution, Bandpass Filter, Migration, and Display. Since the success of the final geophysical interpretation of seismic data is dependent upon the proper completion of each processing step it is often necessary to redo any one or all of the processes based on intermediate results. For this reason and the potential complications in processing "deep towed" array data we recommend that NORDA develop an inhouse processing capability. A basic facility is suggested below based on combining the future anticipated computer resources of NORDA, a CDC Cyber 170, with a dedicated 16 bit mini computer system. This combination will make it possible to place all human interactive data editing operations on an inexpensive mini system, and save the resources of the larger system for all computation bound algorithms. This combination has the advantage of being cost effective and will enable a basic processing facility to be developed quickly with a minimum of specialized programming requirements.

II. SOFTWARE REQUIREMENTS

1. Demultiplex, Edit.

This basic processing step is required to reformat field tapes and recover or eliminate bad data. Seismic field data is often recorded in a multiplexed format on a dedicated system. In this case reformating is necessary for other computer systems to easily recognize the seismic data. In the NORDA acquisition system, it would be desireable to have the field data finalized on 9 track 800 or (preferably) 1600 bpi tape in standard hexidecimal floating point format (or CDC 60 bit floating point format) and to have all instrumentation data extracted and placed in data trace headers. This operation should be done immediately and could be done at sea if the required computer hardware were available during data acquisition. Simultaneously, bad shots, noisy traces etc., should be either be recovered or eliminated. To accomplish this process in the field a 16 bit mini computer with a minimum of 128k bytes of memory, (256k bytes preferred) 2 tape drives, 2.4 mbyte disc drive and graphic display terminal (e.g. HP 9845) are required.

2. STATICS

For the deep towed array data static corrections (reduction of the data to a fixed reference altitude) will be critical to all subsequent processing steps. For this correction two considerations are necessary: First, the arrival time of the Common Shot Point traces must be corrected for variations in array altitude. Second, the offset of the traces must be reduced to accomodate any change in the array aspect angle from the horizontal. For both these corrections proper array instrumentation is vital. Based on the measured altitude of the source and array elements the trace data must be time shifted to a pre-determined reference level and their source-reciever offset corrected. This processing step could be done at sea immediately after the data aquisition and during the demultiplex, edit operation. (The computer hardware requirements are identical to those required for the first processing step.) To perform these initial processing steps at sea would be desirable since they are likely to be time consmuing and require significant manual interpertation and interaction.

3. CDP GATHER

After the Common Shot data have been edited and corrected for statics, they should be combined to form Common Depth Point (CDP) data. Under ideal circumstances where the shot point spacing has been exactly one half the array element spacing (full fold coverage) the CDP gather would be achieved by combining Shot Point 1 trace 1, with Shot Point 2 trace 2, etc. At first glance, it appears that data storage for all the traces of all shots in the CDP gather are required to perform the CDP sort. In fact, storage for only (N(N-1) /2)+N traces, where N is the data fold, are acually required. This is still a large data storage requirement which is usually accomplished using auxiallary storage, e.g. a disc. The proposed 25 channel NORDA array with 3 seconds of .5 msec data will require the storage of 1.95 million data samples. (Errors in navigation may increase or decrease the CDP data fold, resulting in a corresponding increase or decrease in storage requirements.) Since this operation requires large data storage, it is not practical to perform this step at sea during the data acquisition. In the proposed CDC Cyber 170 system, the 200 mega-byte disc system will provide more than adequate storage to gather the deep towed array data, as long as access to the required dynamic storage is maintained.

4. VELOCITY ANALYSIS

Velocity Analysis consists of scanning the array data to determine the two-way normal times and array velocities for hyperbolic trajectories across the array. Usually, every 20 CDP gathers are scanned in this fashion. (In some cases it may be necessary to scan every CDP gather.) This computation is accomplished by time correcting all the traces assuming a constant array velocity for all two-way normal times and computing a coherency statistic, e. g. semblance. This computation illustrates one important requirement of seismic processing, the ability to perform floating point computations in a minimum amount of time. For the 25 fold CDP data acquired by the deep towed NORDA array, velocity scans would be performed for array velocities of 1.5 to 3.0 km/sec in increments of .01 km/sec or less. This requires a minimum of 150 constant velocity normal moveout corrections per scan. Since the semblance computation requires the computation of the sum, and the sum of squares for each two-way time considered the number of floating point operations is significant. For example, for 3 seconds of .5 msec data, and 25 fold CDP data 22.5 million square root computations are required and 46.3 million additional floating point operations are required for the semblance compution.

This computation is ideal for a large high speed mainframe, or when using a 16 bit mini a floating array processor is required. (This computation is totally impractical for a 16 bit mini without an array processor.) Finally, this data must be displayed and manually interpreted. Display is best accomplished using an electrostatic printer/plotter because of the large volume of information that must be represented. (Pen plotters are too slow) Since this data requires manual interaction, the results must be displayed in a quickly recognizable format which is easy to analyze. Ideally a graphic input device (e.g. Digitizing table) should be used to avoid needless delay in interpretation. The result of this step will be a machine readable data base which will be used for the Normal Moveout Correction and Stack. Since the large volume of velocity analyses anticipated in the NORDA application will be based on this same computation, it is desirable to assist the interpreter's decision making process by making the interaction proceed as quickly and conveintly as possible. For this reason, it would be desirable to have the computation performed on the CDC Cyber 170 and the results stored on 9 track magnetic tape. This data would then be displayed on the dedicated 16 bit mini system. Interpretation of this data would be done interactively on this system using either an interactive graphics terminal or digitizing table .

5. NORMAL MOVEOUT STACK

This computation corrects all traces of the CDP gather to two-way normal times based on the results of the velocity analyses. Between velocity analysis points the proper moveout velocity function must be found by interpolation. Although only one moveout correction is applied to each CDP gather (in contrast to 150 or more during the velocity analysis) it must be applied to each CDP gather along the seismic line. This computation is also suited for a large high speed mainframe or a mini computer with a floating point array processor. During this operation it may be desirable to deconvolve and band pass filter each trace before the final combination. Both these operations require high speed floating point capability.

6. MIGRATION

In areas of non-planer reflector geometry the stacked CDP data can be corrected to determine "approximately" correct reflector configuration. The use of a parabolic equation to approximate the hyperbolic wave equation (a narrow beam approximation) still requires high speed floating point capability and large data storage requirements, since a large number of traces are used, e.g. 256 or more.

This computation is again suited for a high speed mainframe with large disc storage. Since storage requirements must be met twice for every sample and trace used in this 2-D (space-time) computation, disc storage for 3.0 million data samples is required to migrate 256 traces with 3 seconds of .5 msec data. This computation can be accomplished on the proposed CDC Cyber 170 system.

7. DISPLAY

Seismic data is usually displayed in a variable area (shaded waveform) format. This format is useful for geophysical interpertation of reflector configuration and continuity. The display itself is accomplished using a galvonometer based camera, or (more economically) an electrostatic plotter. Pen plotters and graphic terminals are inadequate because of speed or hard copy limitations, (The HP 9845 should be suitable at sea for decimated in time, data trace monitors, but not for final display.) Electrostatic plotters are particularly well suited for this type of display because they require "bitset" or raster data as input. For a variable area display, the seismic trace is imagined to be "sliced" into lines where the bits are either on or off depending on whether a data value exeeds the value represented by a particular scan line.

This process is best performed by a 16 bit mini with a dual density electrostatic plotter and a disc or tape storage unit. This operation should not be done using standard vector graphics. In the NORDA application, it will be necessary for the CDC Cyber 170 to perform all post-stack pre-display processes. These include: deconvolution, bandpass filtering, time and spatial gain. The final data tape will then be transfered to the 16 bit mini system for variable area display.

III. HARDWARE REQUIREMENTS

In the above discussion of software requirements, we have specified the required hardware for each processing step. Initally our study was aimed at determing the cost-effctiviness of a dedicated system versus the current NORDA computational facility. (A remote terminal to a CDC 6600 at Eglin AFB) Our effort to determine a true cost for multi-channel processing met with limited success for this system. Trial runs for a Normal Moveout & Stack algorithm indicate a computational cost of $.28/CDP. During a successful cruise, it is possible that 74,000 CDP'S will be acquired. Thus, just the computational cost to perform NMO and Stack would be $2,072. This figure is a minimum since tape I/O, tape storage, tape mounting, and data transferral are not included.

Using the same basis each velocity analysis will cost more than $4.2. A second algorithm used for spectral estimates and deconvolution was run at a computational cost of $.393/ seismic trace. Since this algorithm might be applied to every trace of a CDP Gather, the computational cost exclusive of I/O could be $800 for a successful cruise. Because of considerable uncertainties in the above figures and the anticipated upgrade of the computational facility at NORDA to an on-site CDC Cyber 170 System with 200m bytes of online disc storage and 4 tape drives, we have not pursued this analysis further, but considered a cost effictive utilization of the proposed new system for multi-channel seismic processing. The proposed CDC Cyber 120 system is more than adequate for processing the deep towed array data. The system as specified meets all processing requirements except for display. An additional 9 track drive would be desirable since in the event of a tape drive failure all seismic processing would stop. (All seismic processes will be tape to tape thus requiring continuous usage of two tape drives.) In addition, it is assumed that the 9 track tape will be dual density, 1600 bpi/ 6250 bpi. This will be necessary for inexpensive data archiving in addition to insuring that all processes are not limited by tape I/O.

Aside from these considerations the proposed CDC Cyber 170 system can be used for the following processes:

1. CDP Gather
2. Semblance Velocity Scans
3. Normal Moveout and Stack
4. Migration
5. Deconvolution, Band Pass Filtering, Time and Spatial Gain

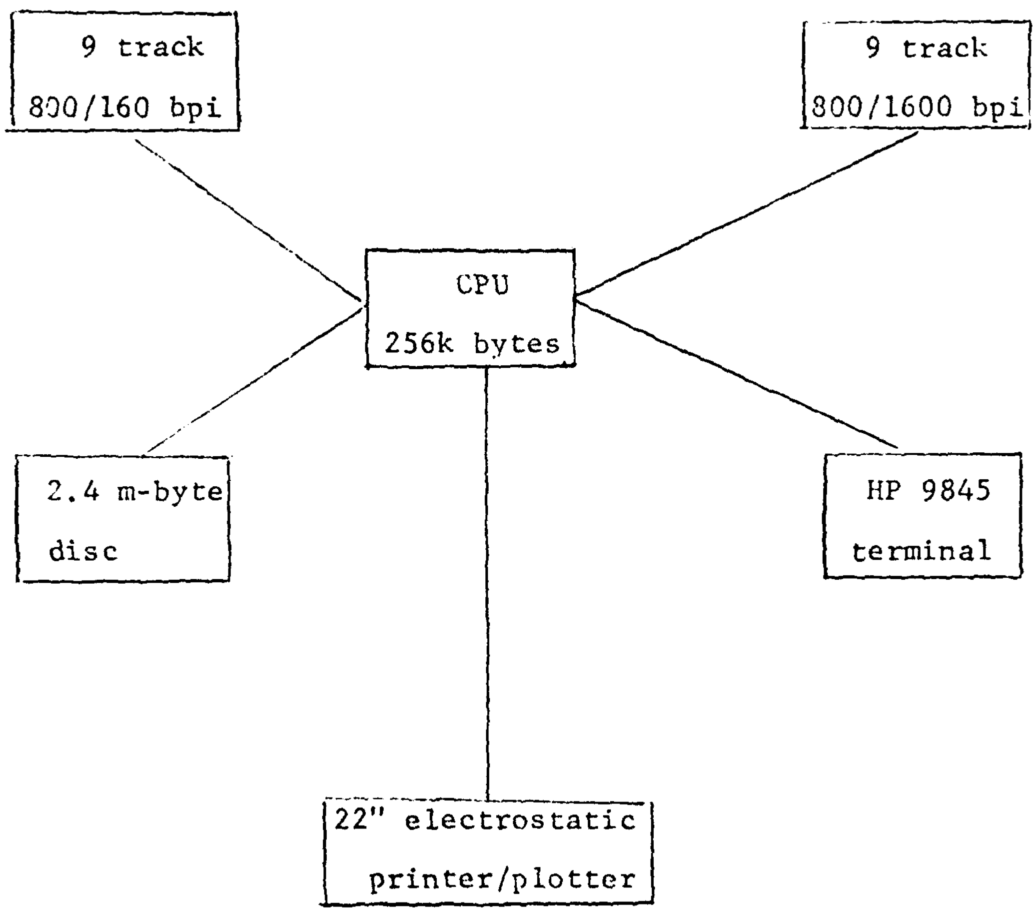
In all cases, the input to the CDC Cyber 170 system should be compatible 9 track 1600 bpi or 6250 bpi data tapes. The 6250 bpi data tapes should be output for intermediate results that will be used as input later to the CDC system or for data that is to be archived. 1600 bpi data tapes should be output only for use on the dedicated system described below.

The proposed CDC system will be suitable for all computational algorithms. The use of this system (in comparison to a dedicated mini based system) for all compute limited algorithms will make it possible to keep computation time and hence cost to minimum. The generation of the required software will also be quick and relativily inexpensive since it can be coded in a high level language, e.g.

FORTAN. This is in contrast to a dedicated 16 bit mini system which requires extensive Assemby language programming. However, this system will probably not be cost effective for the processes which require extensive human interaction coupled with tape I/O. For example, the statics correction may involve manual corrections on a shot by shot basis. To accomplish this a graphics display terminal or plotter and two tape drives are required. The CDC Cyber 170 system could certainly accomplish this process, but two tape drives (or considerable disc storage) would be required for extensive periods of time. Interactive velocity analyses could also be done on the CDC Cyber 170 Stystem but would require access to large parts of the system's resources. For these reasons, and the desire to accomplish some of the basic data editing at sea during the data acquisition, we propose the use of a limited mini computer based system. This system should be capable of use at sea and in a laboratory enviroment. This system would perform the following tasks:

1. Demultiplex Edit
2. Static Corrections
3. Interactive Velocity Analysis and Display
4. Seismic Record Section Display

This system should consist of a 16 bit mainframe with 128k or (preferably 256k) bytes main memory. A 2.4 mbyte disc drive, two 9 track 800/1600 bpi tape drives, and a 22" dual density electrostatic printer/plotter. (An existing HP 9845 graphics terminal can be used for display and TTY I/O.)



The approximate cost for this system is as follows:

CPU w/256k bytes memory* (Data General Nova 4)	20,000
2.4 m byte disc subsystem w/interface	10,000
2-9 track 800/1600 bpi tape drives w/interface (KENNEDY 9300)	16,000
22" dual density electrostatic printer/plotter w/interface (GOULD INC.)	20,000
HP 9845 Graphics Terminal (existing)	N.C.
	66,000

* Based on a Data General Nova 4 System, prices for other systems will vary.

If it is assumed that two 30 day multi-channel deep towed array cruises are completed each year with a data acquision of 74,000 CDP'S (1,480 km) per month, and that these are processed within one year, then over 4 years, a simple linear amortization plus a 12% of initial capital annual rate for service and maintance indicates a cost of less that $9/km for this system:

Capital cost /year *	$1,6500
Service and Maintance +	7,920
Total annual system cost	$24,420
Assuming 2x1480 km are processed /year,	$8.3/km

* assumes 4 year simple linear amortization.

+ assumes 1% of purchase price /month.

One of the principle advantages of the proposed system is the ability for this small scale system to perform reliably at sea. This will permit a substantial speed up in the analysis of the array data. The only practical limitation to this approach is the cost of maintaning such a system at sea. Adequate spares and trained personnel are an assumed prerequisite.

At this time it is not possible to predict the cost for the processes that would run on the CDC Cyber 170 system. But, by partioning the work load between the two systems in the above manner, we anticipate that the cost can be kept to a minimum. In addition, the use of the two systems in the manner described here would keep programming costs to a minimum. The successful implementation of in-house processing at NORDA can be accomplished by one scientist and two programmers working for a period of two to three years. At a minimum, during and after development one scientist and one programmer should be associated with this program on a full time basis.

Finally, out of house processing could be performed initially as part of the acquisition system evaluation. At current costs of $100-200/km for marine data processing (where no static corrections are required and the cost of reprocessing or specialized services for this unique data set are not included) this approach is clearly undesirable for any long term or even modest usage of the data acquisition system.